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Improved earthen stoves in coastal areas in Bangladesh: Economic, ecological and socio-cultural evaluation

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ABSTRACT

The study evaluated the economic, ecological and socio-cultural achievements of improved earthen stoves that were provided to the beneficiaries under a project to improve decreasing biomass energy utilization. A questionnaire was developed and a random sampling method was employed for selecting the samples from the population. The region has undergone a significant change with the development of shrimp aquaculture in brackish water on former paddy field. As a result the households have become dependent on the wood resources of the Sundarban (77% as their first choice of daily fuel). The fuel collection rate from the Sundarban has increased by 30% since the change to aquaculture, while the use of agricultural residues has declined by a similar amount. The introduction of the improved stove with two cook stations and a chimney resulted in a reduction of fuel use (as wood) to 540 g caput^{-1} d^{-1}, from the previous usage of 810 g caput^{-1} d^{-1} using the traditional stove. Households saved 1.5 kg d^{-1} of fuel (one third), and reduced the cooking time by 45 min d^{-1} (about 20%). While 85% of men and 65% of women were the major fuel collectors, the improved stove resulted in a small increase (14 taka) in the women's contribution to family income as well as a monthly saving on fuel cost of 45 taka. Respondents utilized saved time and money for household means and other economic activities.

1. Introduction

Biomass, as elsewhere in the world, serves as a major vehicle for traditional energy generation. Biomass energy covers wood fuel, charcoal, agricultural and forest residues or other plant matter that accounted approximately 14% and 11% of the world's final energy consumption in 2000 and 2001 respectively [1]. IEA [2] estimated that at global level, the share of biomass (14%) in total final energy consumption was comparable to that of electricity (15%) and gas (16%). Developing regions (Africa, Asia, Latin America) record high levels of biomass energy consumption [3,4] in comparison to developed regions. About 25% of the usage is in industrialised countries and the other 75% is used in developing countries [5]. IEA [1] accounted the share of biomass energy in total primary energy supply in 2001 for Asia (25%), Africa (49%), Latin America and the Caribbean (18%) and industrialized countries (3%) respectively. According to the World Energy Assessment, over 2 billion people rely on biomass fuel for cooking, space heating and agro-processing in 16 countries in South and South-East Asia [6]. It is estimated that in sub-Saharan African countries 70–90% of all primary energy is fuel wood used for cooking [7].

Population pressure in developing countries is believed to be the predominant cause of deforestation due to dual needs of food and fuel. Inefficient charcoal production from natural

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forests and woodlands contributes to deforestation [7]. One strategy to reduce stress on forests has been the promotion of improved cooking stoves for use by the rural poor [8]. In a study of 45 urban areas in developing countries, Barnes and Qian [9] found that one third of all household energy expenditure was on fuel wood or charcoal and that energy expenditure accounted for about one tenth of all household expenditure.

Cooking and responsibility for family members occupy a major portion of a woman's daily life (51–54%). By tradition, cooking activity is exclusively performed by women. Women, therefore, fall victim of acute health hazards caused by indoor air pollution associated with the burning of biomass and coal in residences [10]. Studies have shown that women and children are most likely to be adversely affected by particle emissions from biofuels smoke because they spend a significant proportion of their time near biomass based cooking fires [11–13]. Dasgupta et al. [14] provided evidence on PM_{10} and $PM_{2.5}$ concentrations in households living in extreme poverty in typical kitchen arrangements (fuel use, cooking arrangements and structural characteristics) in six regions in Bangladesh. Air monitoring research in Guatemala has indicated that improved stoves can lower indoor PM_{10} concentrations by 50% or more [15,16].

Bangladesh has an agro-based rural economy where more than 85% of its population live in the rural areas. The rural population consume a large amount of traditional fuels for cooking and other purposes. The per capita annual consumption of energy in 1995 was 8.467 Gigajoule (GJ) in Bangladesh. This comprised commercial energy (coal, oil, gas, and hydropower) and biomass fuels that accounted at 3.203 (46%) and 5.264 (54%) GJ respectively [17]. Biomass comprises material of tree origin, such as fuel wood, charcoal, twigs and leaves; agricultural residues, paddy husk and bran, bagasse, jute sticks and animal dung. The total amount of biomass fuel consumed in 2000 was approximately 45 Mt [18]. Among the biomass fuels, agriculture residues contribute 45%, while fuels derived from trees contribute only 15% to the national total. The domestic and industrial sectors consume 42% and 11.4% biomass fuels respectively [18].

The traditional stove commonly used in Bangladesh is a mud-built with three raised points on which the utensils are stored. One opening beneath these raised points is used as the fuel feeding port. Much of the hot flue gas emits from the gap between three raised points and cooking pot. The stove may be built under or over ground. The traditional stove suffers excessive loss of heat because of reducing the convective heat transfer due to long distance between the pot and fuel bed (depth ranging from 30 to 60 cm). The efficiencies of those stoves vary from 5 to 15%, depending on the depth of the stove and size of the flue gas exits [19]. Improved biomass stove, biogas plant and solar cooker are the options for substitution of the traditional stove where indigenous energy sources and materials are used.

The South Western coastal area of Bangladesh is characterized by multiple resource systems, which are generally considered as common property resources. Due to this, they are over utilized and hence rapidly degraded. Competition for resources among multiple users results in social, economic, environmental and political disturbances. The increasing international demand and high prices of shrimp have led to the conversion of agriculture land to brackish water aquaculture and started changing the total ecosystems in the coastal area. High population pressure also results in invasion of the nearby mangrove forest, the Sundarban (the world's largest single productive mangrove forest), in order to harvest wood, honey, shrimp fry collection and other economic resources.

The improved earthen stove has been distributed for free of cost to the beneficiaries under a project component of Sustainable Environment Management Program of the Ministry of Environment and Forest of the Government of Bangladesh. The project started in October 1998 aiming at establishing environmentally sustainable, economically viable and socially equitable coastal resources management through a community based approach. Providing improved earthen stove to the women beneficiaries was an input among others in course of project implementation. The objectives of this study were to make an evaluation of its impact on the environment, socio-economic and economic aspects.

2. Methods

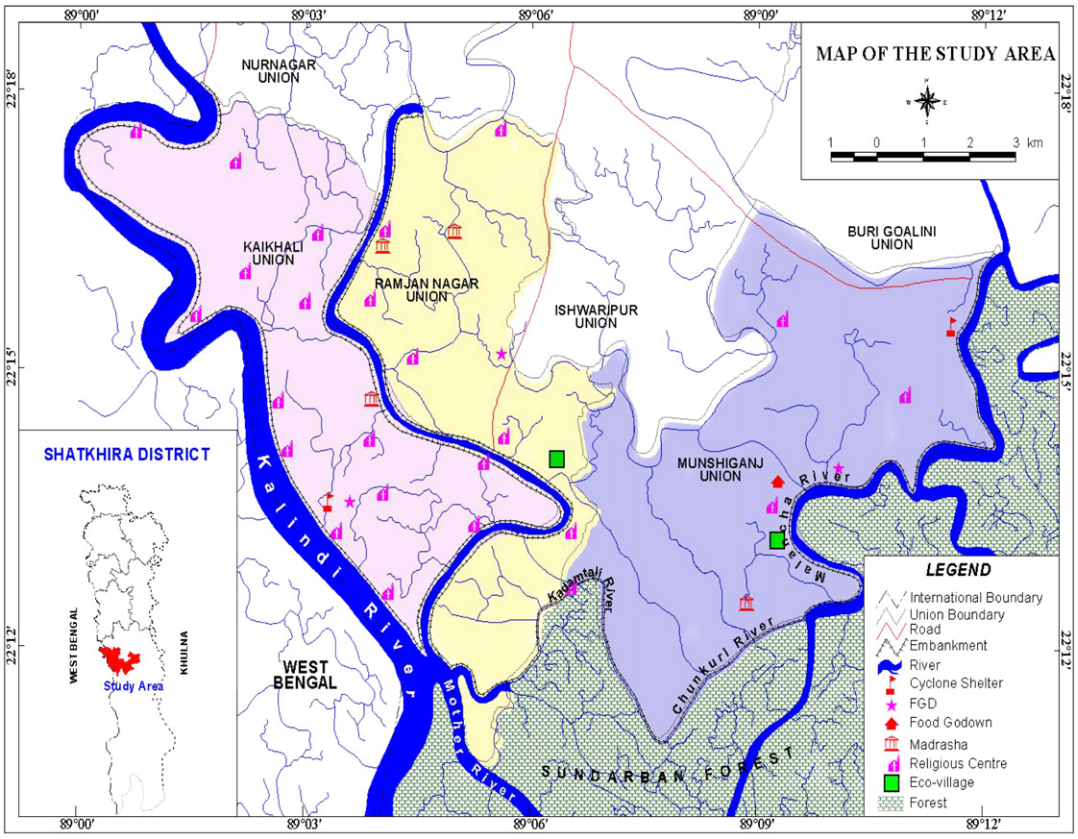
2.1. *Profile of the study area*

The study area is situated at 22°11'-22°17'N and 89°03'-89°12'E, in the brackish water area of south-western Bangladesh (Fig. 1). The Sundarban lies to the south and east. It is separated by the Kadamtali, Malancha, Dumkoli and Chunkuri rivers. The Bay of Bengal lies beyond the Sundarban to the south of the study area and the river Kalindi bordering India to the west [20]. Administratively, the study area consisted of three Unions namely Munshiganj, Ramjannagar and Koikhali under Shyamnagar Upazila of Satkhira District. The total population of the three Unions was 79,404, which was 26.38% of the Shyamnagar Upazila [21]. Of the total, Munshiganj Union has 32,252 populations (10.71% of the total Upazila and 40.62% of the project area). The Union Ramjannagar has a population of 21,862 (7.26% of the total Upazila and 27.53% of the project area). The rest 25,290 populations (8.4% of the Upazila and 32.42% of the project area) belong to Kaikhali Union. The total populations of the project area were 12,403, which was 26.62% of the Upazila.

2.2. *Description of improved earthen stove*

The improved earthen stove is an upgraded and modified version of traditional stove used mainly by the people in the village. The improved stove is built with good clay subsoil in the kitchen or outside the kitchen. Low cost materials and simple technology are applied to make it safe, easy, inexpensive and effective.

In the stove there are two chambers (Fig. 2). In the first chamber fuel is burnt and cooking takes place through the direct heat from the fire. The combustion products from the first chamber enter the second chamber through a space of 12.5 cm diameter and provide heat for cooking in the right chamber. Later the smoke is carried away from the chambers by a chimney (2.5 m length × 7.5 cm diameter and constructed



Source: [20]

Fig. 1 – Map of the study area.

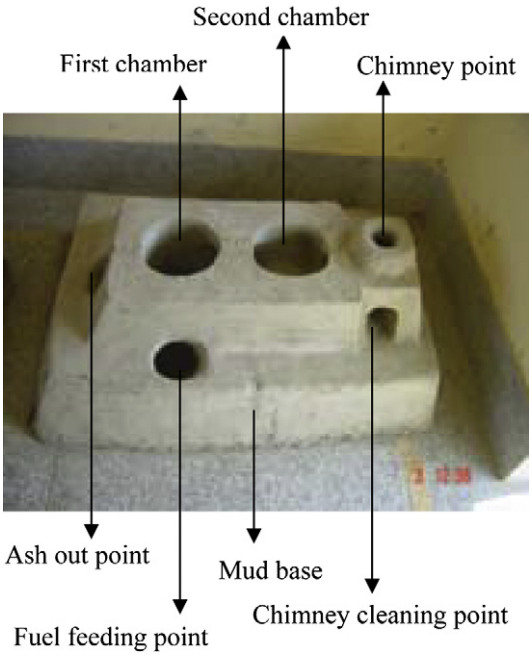


Fig. 2 – Improved earthen stove.

by rod, cement and concrete materials) through the roof of the kitchen. Below the chimney, there is another point to clean the chimney. Inside the first chamber, there is an iron made grate at 20 cm below the pot where fuel is placed. This grate is also used to filter out the ash onto the bottom. Just above the frame there is an opening to push the fuel into the first chamber. The bottom of the second chamber is filled with earth so that a 5–7.5 cm gap remains between the pot and the bottom. At the bottom of the grate in the first chamber there are two openings each 12.5 cm in diameter, one to let air in

Fig. 3 – Traditional stove.

and the other to let ash out. There are no raised points at the mouth of the stove unlike in the traditional model (Fig. 3). Thus there is no gap between the pot and the stove and no way out for the heated gas or smoke from the stove into the kitchen. The improved stove costs 100 taka that includes good clay subsoil, chimney and labour.

2.3. Sampling

The study was conducted on a random sampling of 60 (20%) users drawn from 300 recipients of improved earthen stove living in the project area. Data collection was done by interview and observation using structured questionnaire that consisted both closed and open-ended questions. The questionnaire contained includes demographic features of the stove users, economic (fuel saving, time saving), ecological (source of fuel, types of fuel, environmental awareness) and socio-cultural aspects (utilization of saved money and time). The study process was conducted with the participation of the wives of the household heads who received the improved stoves under a project.

2.4. Analysis of data

The fuel utilization was calculated as what the participants estimated when they collected or bought from different sources. Total quantity of fuel is expressed as = The total amount of fuel used daily by the studied family × the total households.

Total cost is estimated as = One taka kilogram^{-1} of wood fuel, which was the local market value during the study period. (1 taka = US$ 0.016 in August 2006).

Time saved due to improved earthen stove is expressed as = Time required for cooking using traditional stove − time required for cooking using improved earthen stove.

3. Results and discussion

It is observed that out of 60 users, 43 (72%) families used the improved earthen oven regularly, while 17 (28%) families used the new stove during a specific period of the year, i.e. the rainy season. The average family members were found to be 5.55 among the surveyed family, which was lower than the average family members (5.69) of the Shyamnagar Upazila.

There was little chance to work outside the vicinity of the homestead before the introduction of shrimp culture into the area. Women have become involved in the process of shrimp culture as an alternative source of occupation. Besides household activities, these women catch shrimp fry and get employment in shrimp farms. Many of the women do not recognize household work as a primary occupation and as this does not give them any monetary value. From the survey 21% women did household work as their primary occupation. 75% women had secondary occupation as shrimp fry collection while only 4% had fry collection, labouring at shrimp farm as tertiary occupation.

The monthly average income of the male head of household was found to be 2650 taka. The monthly average income of a woman was 139.09 taka. Majority (26.67%) of the households had monthly income between 2000–3000 taka while only 5 (8.33%) had over 5000 taka (Table 1).

Table 1 – Monthly income of the household heads.

Monthly income (Taka)	Numbers of households	% of households
<1000	6	10
1000–2000	13	21.67
2000–3000	16	26.67
3000–4000	12	20
4000–5000	8	13.33
>5000	5	8.33
Total	60	100

3.1. Economic evaluation

The economic evaluation was assessed through money saving, time saving using improved earthen stove and on the other hand as income generating by selling stoves.

3.1.1. Fuel and money saving

It was revealed from the study that there was less demand for fuel in improved earthen stove compared to the traditional stove. The study showed that a family of 5.55 members (average) consumed 3 kg fuel daily in improved stove with compared to 4.5 kg in traditional stove and saved 45 taka month^{-1} (fuel cost 1 taka kg^{-1}). The total fuel consumption across the population decreased by one third from 55.81 tonne to 37.21 tonne annually. If it is calculated after the estimation of 50% by BCSIR [22] then the saving under these three Unions would be 27.91 tonne per day and 101,85 tonne in a year. This finding also conforms to the report of the World Bank [23], where in Niamey (Niger), the typical amount of wood used in a traditional stove was 0.7 kg person^{-1}day^{-1} and with an improved stove the amount declined to about 0.4 kg. The total family saved 335 kg of wood, valued at just over $15 year^{-1}. In Rwanda a family that adopted improved charcoal stoves saved about 394 kg of charcoal worth $84, while reducing daily consumption from 0.5 to 0.3 kg person^{-1} [24]. Similar, in Kenya indicated an average decline in daily charcoal consumption from 0.7 kg to 0.4 kg person^{-1} with an improved stove [25], adding up to a total yearly saving of 613 kg family^{-1}, with a value of about $65. Brinkmann [7] also reported 50% fuel wood saving was achieved by household using improved stove in Malawi.

3.1.2. Time savings

Most stove users mentioned that time saving as an achievement, but in most cases the saved time did not calculate and specified. The stove users experienced time saving during the cooking process. They explained that the improved stove cooked faster than the traditional stove. The study showed that it took only 2.25 h to cook in improved stove compared to 3 h in traditional stove for the same family members. Thus, 45 min (25% of cooking time) was saved, which correspondence to time savings of 57% in low cost clay stove [26], 43% in Tsotso stove in Northern Namibia [27] and 27% in wood burning device [28] respectively.

3.1.3. *Other economic achievements*

Before the introduction of the improved earthen stove, the contribution of respondents to their families' income was 5.01% per month (125.33 taka month^{-1} out of an average monthly family income of 2503.33 taka month^{-1}). After the introduction of the improved stove their contribution increased to 5.25% (139.17 taka month^{-1} out of an average family income of 2650 taka month^{-1}). While the reasons for this increase are varied, the improved stove played an important role in saving time and gave them an opportunity to serve as paid labour outside the home. The contribution of women in the study area to monthly income varied between 1% and 40%, of which the average monthly contribution was 5.25%.

The other economic achievement of stove users was income generation through construction of improved stoves upon getting an order. The stove makers were given training and became the resource persons in the villages. The stove maker earned 150 taka in setting of each stove for their labour and other accessories and a number of women have taken this as an enterprise and benefited economically.

3.2. *Ecological evaluation*

Ecological evaluation was made in terms of use of fuel sources, types of fuel and environmental awareness among the people in the study area.

3.2.1. *Sources of fuel*

When procuring biomass, rural households commonly availed all accessible sources. Many (95%) households preferred using multiple sources to obtain different quality of fuels. Six different sources of biomass fuel were identified in the study area as homestead, agriculture land, market, domestic animal, local area and the Sundarban. 76.67% of the respondents preferred Sundarban as their first source of daily fuel needs and the use of the Sundarban resources has been increased by 30% after shrimp culture began into the study area. Fig. 4 compared sources of fuel availability before and after the introduction of shrimp aquaculture. Fuel use from the vicinity of home decreased by 15% due to the continuous loss of homestead forest resources. Moreover, biomass sources from the local area, domestic animal and agriculture have been reduced by more than 10%, 20% and 30% respectively due to shrimp aquaculture. However, purchasing fuel wood from market sources were increased by 18% after the shrimp culture.

In the study area, 95% of the respondents were involved in fuel collection. 41.67% of the families collected fuel and 53.33% collected and bought fuel from the market. Only 5% of families bought all their fuel. Males (85%) were identified as dominant collectors of biomass fuel from the Sundarban, followed by children (10%) and females (5%). From rest of the sources, females (65%) were found dominant collectors of biomass fuel followed by children (30%) and males (5%).

3.2.2. *Types of fuel used*

A large number of people in Bangladesh rely on rice husk as an important source of fuel. The decrease of such resources in the study area made people dependent on the leaves, branches and fruits of mangrove trees of the Sundarban. In the Sundarban, seeds of some trees are germinated while came in contact with mud in the riverbank. The poverty driven people in the area collect these seeds during low tide and use as fuel after drying resulting obstruction of natural growth of the trees in and around the Sundarban. It is revealed that the respondents preferred wood (71.67%) as their first choice of biomass fuel because of its accessibility in and around the Sundarban. Branches of trees (65%) occupied the second largest position followed by leaves (60%) and cow dung (43%) respectively (Fig. 5). Rice straw (35%) was the lowest preference because of reduced availability in the area as most of the fields were occupied by year round shrimp aquaculture. This result agrees with the findings of Jasimuddin et al. [29] and Miah et al. [30], where they found stems and branches were the predominant contributors to the household fuel supply in two south-eastern coastal areas and one hill area in Chittagong, Bangladesh respectively.

3.2.3. *Environmental awareness*

One of the objectives of the project was to ensure protection and conserve the natural resource and use of environment friendly technologies. The communities in the study area have well received the general awareness of environmental issues and their relationship with the ecosystem that affects their landscapes and lifescape. The project made the villagers aware of the conservation laws, acts and rules.

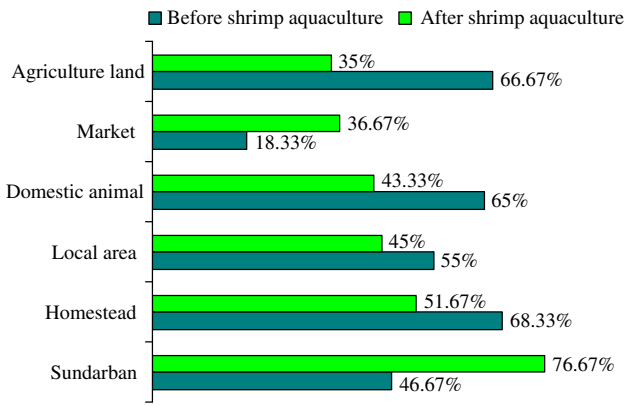


Fig. 4 – Sources of fuel.

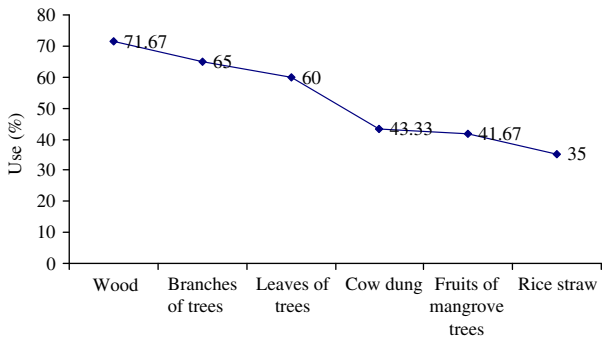


Fig. 5 – Types of fuel.

The project established three environment schools since 2000 to promote environmental education along with national curriculum among the children (aged between 8 and 15) of the neighbourhood. The children of these schools are now aware of many important conservation messages even they do not make any illegal collection of resources from the Sundarban while they go with their parents. The children now do not collect the seeds of mangrove that come with the tide rather help in germinating on the mudflat. The conservation education in the environmental school keeps away the children in destroying aquatic flora and fauna.

3.3. *Socio – cultural evaluation*

The socio-cultural achievements were identified with regard to utilization of saved time and money, which in turns influenced by economic consideration.

3.3.1. *Utilization of saved money*

The saved money brought improvements to family life. Many applications were mentioned in order to the alternative use of saved money. Most (85%) of the saved money was used for household means or buying foods. Some (55%) spent money on books for children. 85% of the respondents opened an account in local banks for saving while 45% invested in income generating activities.

3.3.2. *Utilization of saved time*

The women spent extra time in other activities with great enthusiasm. They contributed saved time in economic activities like rearing poultry (65%), cattle (35%), shrimp fry catching (85%), sewing *kantha* (traditional blanket) (45%), tailoring (25%), gardening (20%) and other homework, which benefited economically and contributed in improving their family life. The children also used their saved time on education rather than collecting fuel as before.

4. Conclusion

The energy saving improved earthen stove has brought several changes and improvements in fuel usage, economic, environment and socio-cultural aspects. The introduction of the improved stove is a safer, cost saving and proven technology that meets the needs of the users. Fuel savings reduced outlays for purchasing wood, shortened collection times, alleviated local pressure of fuel resources and diminished air pollution.

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